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COMPARATIVE PHYSIOLOGY AND PSYCHOLOGY.

BY S. V. CLEVENGER, M.D.

THE science of psychiatry will advance in proportion to the development of psychology based upon comparative microscopic anatomy and a physiology into which molecular physics shall enter more in the future. The entire fabric will be a triumph of monism, for if we set out on any other assumption, such as the dualistic affords, than that mind is a product of chemical energy and other natural forces, there is an end to inquiry.

The baleful influence of teleology hangs over the average physiologist as over the superstitious laity and debars him from seeing things as they really are. The inability to conceive of consciousness as a product of the motions of matter is on a level with the inscrutability of the nature of ultimate force and atoms. In dealing with the workings of the mental mechanism it is not necessary to define or attempt to explain consciousness any more than the practical electrician or chemist or optician finds it necessary to define or speculate upon the ultimate nature of the vibratory terms in which they deal. As the physicist increases his knowledge of *how* matter and motion act and react upon each other, he is willing the metaphysicians should quarrel over the unknowable, the lunar politics. With the dawn of comparative psychology the truth began to appear, theories became subordinated to facts and not facts to theories.

Not only are the laws which bind the social organism similar to and derived from those which govern the units of which it is composed, but the protoplasmic units are governed by the same processes down to chemical affinities.

H. C. Sorby[1] estimated the number of molecules in $\frac{1}{1000}$ inch sphere of albuminous substances to be

Albumen	10,000,000,000,000
Water	520,000,000,000,000
Water in molecular combination	530,000,000,000,000

and claims that we are as far from seeing the ultimate constitution of organic matter with our highest and best powers as the naked eye is from seeing the smallest objects which they now reveal to us, and that there seems no hope that we may ever see them, for light is too coarse.

This is a limit to our sense appreciation of the subject. Reason enables us to make safe guesses beyond the senses, but having them for a guide and acknowledging that science does not require final but effective causes.

The "selection" of food which is suited to the Amœba becomes "selection" or mere chemical attraction depending upon how you look at it. For instance, let the assimilable pabulum consist of molecules for which the protoplasm has affinities or attractions, the Amœba will not only be drawn to it locomotorially, but will fuse about it. As it is drawn into and becomes part of its tissue, there is undeniable chemical union, the inert resulting matter is left behind or excreted in the movements. The inert matter not only does not attract the animal, but even its passing by or over it the assimilative motions are not provoked. There could be an endless wrangle over the nature of this act of the protozoön, for it involves the most weighty considerations in all life. There is much to be said on all sides, but the moment the acknowledgment is made that chemical affinity and other physical influence is not the so-called will power of the Amœba, that moment there is an end to investigation. Admitting that these natural causes exert entire control of the protozoön, and forthwith the postulate proves its correctness in exact proportion to the correctness of the logical methods used in reasoning therefrom.

Much of the perplexity into which the student has been thrown by regarding these movements has arisen from want of consideration of the composition of resultants of attraction from many points in the medium or environment due to light, heat, eddies, vortices, disseminated invisible attracting points, the assimilative process itself changing the conditions of attraction, as in plethora;

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[1] Presidential address Royal Micros. Soc., Feb. 2, 1876.

as might be expected, movements cease, owing to combinations being satisfied for the time. Then too the simple nature of protoplasm has been by no means proven. It is being regarded as not only complex through atomic union, but as holding in its molecular construction secrets which the chemist may some day find operative in the inorganic affinities. There may be, as has been surmised, many kinds of protoplasm, and the ultimate basic substance may be beyond. The ova of the different animals seem to be protoplasm plus other things, differing from each other in quantities and composition. We know that certain animals add to their bodies chemical substances which form tissues, and that other animals do not, showing a variability of selective affinity. The psychologist who attempts to explain consciousness on the basis of molecular reaction is no more at a loss than the chemist who accepts such words as catalysis and isomerism as representing acts of the atoms.

Starting out, then, with the fair understanding that the Amœba moves by virtue of the operation of physical causes, and that speculations upon the origin of matter and force are foreign to the subject, we will see to what the assumption, if you choose to call it one, will lead.

I invite earnest attention to the proposition I make here as a corollary from the apparent volition of the Amœba being molecular attraction.

Locomotion and prehension of the Amœba are due mainly to extrinsic forces operating immediately upon its organism, whereas these phenomena in man and the majority of the intermediate metazoa are due immediately to intrinsic forces, as a rule, preponderating over the extrinsic, but nevertheless the extrinsic remain the remote causes of motion in all animals.

In this there is a view of the evolution of volition from the so-called involuntary, its growth from the chemical affinities.

The belief is current among biologists that if we reverse the conditions under which all life exists, all life would perish; if the reversal were slowly effected most would perish and but few survive; if inappreciably slowly, it is highly probable that the number of surviving forms would be very large. The survival of any animal is evidence of its consonance with its surroundings, and the environment not only modifies and acts upon the animal to develop or destroy it, but also, from our chemical standpoint, originates it. Without dipping into biogenesis, spontaneous generation somewhere, somehow, is consistent with the groundwork of our essay, but we will avoid its consideration.

Spallanzani, Dugès, Doyère and others have demonstrated that Infusoria and certain low worms, the Rotatoria, Tardigrada and some Crustacea are capable of desiccation and revival. The suspension of the major evidence of life function by animals under changed conditions, whether this be absolute desiccation or not, the development of seeds and ova, after indefinite quiescence, point toward if they do not fully attest the merging of the inorganic into the organic, and the addition of the faculty known as life through the restoration of the medium which affords the means for the molecular motions which go to make up all there is in life. So the restoration of frozen fish, and as Semper cites: "Amphibia, Mollusca and other forms have lived years without food." He "kept species of land snails for years, wrapped in paper and quite dry, in wooden boxes, and thus wholly without food, and many of them are at this day alive and active." His explanation is: "The amount of nourishment required daily by any animal must naturally be equivalent to the organic matter which is daily used up in the various organs to keep up the vital processes; the more active an animal is the more food will it require. But the vital processes of animals as low in the scale as Amphibia or univalves are extremely feeble; their respiration, even under the agitating influence of propagation, fails to raise temperature appreciably. In such the vital processes may be reduced to a minimum without loss of life."

The whole matter is one of degree, for warm-blooded animals live but a little while unfed. Hibernates are comparable in condition to "cold-blooded," while this division sustain an arrest of nutrition longer, and finally in the lowest forms the approach toward almost indefinite suspension leads us to think that there is a point where life and mere chemical conditions are identical. The repeated withdrawal of that which renders life evident entails no permanent inconvenience. Such embryos as are capable of living in a medium such as strong alcohol several days, point to the mechanical nature of certain low stages of life and the diminished liability to destruction of initial forms through heterogeneity of environment. The internal tissues of man, with their great range of chemical natures of fluids in which the cells thrive, instance this. With differentiation and higher organization comes the increased necessity for stability of environment, paralleled by the ability of low forms to reproduce lost members, not evident in developed life.

We may regard the Amœba in many ways as having undergone development above some lower form; but pending the settlement of the bathybius question, and with a mere glance at Protista and preamœbic life, the organism affords us a convenient starting point for inquiry. While physiologists agree in its possession of the fundamental activities of life in simplest modes of manifestation, they usually content themselves with a mention of this fact and proceed to examine complex differentiated tissues as though the Amœba merited no further attention. From my way of looking at it, the Amœba, containing the solution of so much, deserves very deep consideration, which being accorded it, the apparently simple becomes intricately complex in that it explains so much.

First the environment of the Amœba: Stagnant water, mud or damp earth, or from the infusion of any animal substance in water and allowing it to evaporate while exposed to direct sunlight.[1]

It absorbs oxygen and gives out CO_2. 45° C. and strong shocks of electricity kill it; moderate shocks of electricity causes it to assume the globular still form. Crushing kills it and then even the nucleus disappears. Freezing point arrests motions. In its surroundings there are, besides its food, air, water, mineral matter, sunlight, heat and cold, mechanical vibrations.

At 35° heat stiffens it, at once proving the development of the Amœba for its medium, and that of the white blood corpuscle, which is more sluggish, for a different one, the temperature of the blood currents of the different animals. This may be regarded as an acquired adjustment.

Its molecules are subject to the law of gravitation. Light attracts it; heat increases, within limits, its activity; vibrations, such as eddies of its medium, move it; electricity stuns it; its intimate structure assimilates, chemically, the substances for which its molecules have affinities, and being nonresponsive to those for which it has not, consigns them to the exterior.

Now if all these forces act upon and in the Amœba, what is to prevent external forces from pulling or pushing out its pseudopodia, and with the cohesion of its mass flowing its granules into the pseudopodium most attracted, and thus drawing it bodily in the line of the resultant of all its external and internal forces. The multiplicity of the components of the resultants are evident upon watching it.

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[1] Practical Biology, Huxley and Martin.

However highly differentiated the desires of man may be, and however he may fail to recognize the attraction of his own cells for pabulum, as soon as the food is placed within reach of the enteric cells, *their* affinities are not masked. If a complex organic protoplasm has the capacity of chemical conversion and union with oxygen and other molecules, and at the same time the union of oxygen with hydrogen under the proper circumstances is through such conditions which favor the mutual attraction at a distance, we cannot avoid the idea that a similar effect is produced upon the bioplasm, and that affinity for its food is a chemical energy which is one of the forces forming, with other modes of motion or attraction, a resultant, each of these attracting inversely as the square of its distance, and directly as its mass. Because the protozoön does not go straight toward its food, it is thought not to be attracted by it, but when in contact the pseudopodia envelop it, then it is said to be a will effort. When in contact then the assimilation is possible and chemical energy asserts itself as a larger component of the general forces which make resultant motions, when at a distance the food becomes one among many influences upon its movements.

Prehension, which is here evidently locomotory, is for the obtaining of food, and is caused by a number of natural extrinsic forces or attractions combined with a lesser number of intrinsic forces or attractions.

Chemical affinity is the prime cause of assimilation. Locomotion is evidently here only a form of the latter, due to the former as a direct cause, not accidentally aided, often interfered with, by other similar natural forces, inasmuch as the Amœba may be drawn away from his food unless it be near enough, or there be a compensatingly large enough amount to draw it against opposing attractions.

Throughout animal life to the highest with the development of food-procuring faculties this rule still holds good. The more the faculties increase the more direct is the food acquisition and the less do generally coöperate, but in this regard interfering forces influence food procuring. Atavism is prominent in doing that which drives from a base of supplies or want of foresight in improvidence.

Prehension is an accessory to locomotion, and both are assimilative acts, or acts which have for their end the assimilative.

This also is evident in full development, for every act or movement of the body is of a prehensile nature. Leg movements take hold of the ground through gravitation to carry the body in search of food; hands and arms being directly prehensile; jaws are prehensile in their food grasp; ribs are prehensile in their assisting oxygen introduction, that gas being a food. In snakes the ribs are locomotory prehensile.

We thus have all the physical forces, including gravitation and chemical energy, acting upon the low organism to cause *all* its motions. Just as the heat of the sun overcomes by its gravity the earth's, and lifts billions of tons of water from the ocean to allow it to fall again in obedience to terrestrial attractive force, so may the "vitality" of an animal or plant, *apparently* working against physical laws, lift the child from the embryo, the tree from the seed, but eventually the cycle is complete and the primitive elements are separated in "death" to reënter at once upon other changes. The natural forces are masked in life-phenomena as the law of gravitation is, though the direct agent, not recognized in the upward rush of the fountain.

The Amœba assimilates organic matter and breathes as it uses up oxygen and exhales carbonic acid. To complete the objective study of the Amœba we observe that it *grows* as a consequence of its eating, and that owing to its growth and the operation of the attraction of gravitation, a force too often neglected in consideration by physiologists, *fission or reproduction* occurs, as the cohesive attraction of its molecules cannot pass beyond a certain limit, and the extra weight is gravitated, *excreted* off, a process still evident in all animal reproduction and through excretory channels also.

We also see that the sexual act is *identical* with eating in the so-called neutral, genuine hermaphrodite, form. This is more apparent in other Protozoa as a differentiation. I append my article on this subject from *Science* (N. Y.), June 1, 1881:

A paper on Researches into the Life-history of the Monads, by W. H. Dallinger, F.R.M.S., and J. Drysdale, M.D., was read before the Royal Microscopical Society, Dec. 3, 1873, wherein fission of the monad was described as being preceded by the absorption of one form by another. One monad would fix on the sarcode of another and the substance of the lesser or under one would pass into the upper one. In about two hours the merest trace of the lower one was left, and in four hours fission and multiplication of the larger monad began. A full description of this interesting phenomenon may be found in the *Monthly Microscopical Journal* (London) for October, 1877.

Professor Leidy has asserted that the Amœba is a cannibal, whereupon Mr. J. Michels, in the *American Journal oj Microscopy*, July, 1877, calls attention to Dallinger and Drysdale's contribution, and draws therefrom the inference that such cannibalistic act of the Amœba is a reproductive one, or copulative, if the term is admissible. The editor (Dr. Henry Lawson) of the English journal, Oct., 1877, agrees with Michels.

Among the numerous speculations upon the origin of the sexual appetite, such as Mandeley's altruistic conclusion, which always seemed to me to be far fetched, I have encountered none that referred its derivation to *hunger*. At first glance such a suggestion seems ludicrous enough, but a little consideration will show that in thus fusing two desires we have still to get at the meaning and derivation of the primary one—desire for food.

The cannibalistic Amœba may, as Dallinger's monad certainly does, impregnate itself by eating one of its own kind, and we have innumerable instances among Algæ and Protozoa of this sexual fusion appearing very much like ingestion. Crabs have been seen to confuse the two desires by actually eating portions of each other while copulating, and in a recent number of the *Scientific American* a Texan details the *Mantis religiosa* female eating off the head of the male Mantis during conjugation. Some of the female Arachnida find it necessary to finish the marital repast by devouring the male, who tries to scamper away from his fate. The bitings and even the embrace of the higher animals appears to have reference to this derivation. It is a physiological fact that association often transfers an instinct in an apparently outrageous manner.

With quadrupeds it is undoubtedly olfaction that is most closely related to sexual desire and its reflexes, but not so in man. Ferrier diligently searches the region of the temporal lobe near its connection with the olfactory nerve for the seat of sexuality, but with the diminished importance of the smelling sense in man the faculty of sight has grown to vicariate olfaction; certainly the "lust of the eye" is greater than that of other special sense organs among Bimana.

In all animal life multiplication proceeds from growth, and until a certain stage of growth, puberty, is reached, reproduction does not occur. The complementary nature of growth and reproduction is observable in the large size attained by some animals after castration. Could we stop the division of an Amœba, a comparable increase in size would be effected. The grotesqueness of these views is due to their novelty, not to their being unjustifiable.

While it would thus seem apparent that a primeval origin for both ingestive and sexual desire existed, and that each is a true hunger, the one being repressible and n higher animal life being subjected to more control than the other, the question then presents itself: What is hunger? It requires but little reflection to convince us of its potency in determining the destiny of nations and individuals and what a stimulus it is in animated creation. It seems likely that it has its origin in the atomic affinities of inanimate nature, a view monistic enough to please Haeckel and Tyndall.

Dr. Spitzka, in commenting on the foregoing in the same journal, June 25, 1881, says:

> "There are some observations made by alienists which strongly tend to confirm Dr. Clevenger's theory. It is well known that under pathological circumstances relations obliterated in higher development and absent in health, return and simulate conditions found in lower and even in primitive forms.
>
> An instance of this is the *pica* or morbid appetite of pregnant women and hysterical girls for chalk, slate pencils and other articles of an earthy nature. To some extent this has been claimed to constitute a sort of reversion to the oviparous ancestry, which like the birds of our day sought the calcareous material required for the shell structure in their food (?). There are forms of mental perversion properly classed under the head of the degenerative mental states with which a close relation between the hunger appetite and sexual appetite became manifest.
>
> Under the heading "Wollust, Mordlust, Anthropophagie" Kraft-Ebing describes a form of sexual perversion where the sufferer fails to find gratification unless he or she can bite, eat, murder or mutilate the mate. He refers to the old Hindoo myth of *Civa* and *Dúrgá* as showing that such observations in the sexual sphere were not unknown to the ancient races. He gives an instance where after the act the ravisher butchered his victim, and would have eaten a piece of the viscera; another where the criminal drank the blood and ate the heart, still another where certain parts of the body were cooked and eaten.[1]

Nature, London, commenting on my article, quoted. "Mulieres in coitu nonnunquam cervicemque maris mordunt," from Ovid, I suppose.

The locomotory, which exhibits all the prehensile acts undifferentiated, is a product of a number of natural forces, and so far as we can speak of atoms having objects, the object of locomotion is food procuration.

Prehension, locomotion, assimilation, growth, excretion, reproduction are so combined as to appear inseparable, all are molecular motions integrating to form mass motions, and the latter to facilitate the first.

Keeping this in sight as a biological fact it will simplify subsequent inquiry.

Adjustment and readjustment of the animal perpetually occurs, the reaction of the protozoön upon its environment is possible only through the intimate structure of the animal having been modified by the environment, this consists in molecular changes ending in mass changes.

This tendency is exhibited in the frequent appearance of a part unable to throw out pseudopodia, which gravitates to the rear and thus becomes the hinder part, this occurs in the proteus animalcule temporarily, and in other Amœba forms as a permanent differentiation.

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[1] Ueber gewisse Anomalien das Geschlechtstriebes. Von Kraft-Ebing. Arch. f. Psychiatrie, VII.

The ectosarc is composed of denser but mobile material due to separation of granular and molecular matter by natural causes.

The vacuoles are with reason assumed to be watery or gaseous spots filtered from the assimilative process, their constant appearance and disappearance are doubtless chemical and mechanical. The CO_2 and water holding in solution or suspension fine excretory material will find its way out through diffusion, and the elasticity of the sarcode with other larger particles gravitated out through any temporary channel. This process is apparent, though better provided for, in cloacal animals whose watery, gaseous and solid excreta are poured forth from fixed, often the same orifices. The gastræa stage is this condition in full.

If with ingestion of food and oxygen the animal increases its bulk faster than the ectosarc can accomodate itself to the change, extraneous matter, such as carbonic acid and water, *must* be propelled away from the protoplasm for which it has no affinity, and under the operation of incessantly recurring similar causes it is not surprising that this rythmical diastole and systole should often become quite regular.

We thus have inspiration of oxygen as an assimilative act in its affinity for the protoplasmic molecules together with the other accretive atomic motions and elasticity of the ectosarc instituting rythmic contractions to expel inert products. If this be admitted then *the inspiratory oxygenation of every enteric and arterial cell from the food and blood is the direct cause of vermicular motion and pulsation.*

The motions of the Amœba are assimilatory, prehensile locomotory, accretory, inspiratory, expiratory, excretory, reproductory.

Turning now from the objective method let us examine this primitive form subjectively. The objections to an application of the latter process to amœbic movements are equally valid against all other animals, even man. We know nothing of the workings of consciousness in others except by comparing like effects and inferring from them similar causes. We have the various molecular and molar workings of the Amœba as a guide in determining what it feels, likes and dislikes. Descartes' conclusion, "Cogito ergo sum," Huxley regards as "non sequitur." I would merely postulate both ends of the sentence as being for physiological study, unassailable: "Sum et cogito," and let the metaphysicians wrangle over the rest. The Amœba's functions are simple but nevertheless the same as our own. Forthwith we must assign it a desire for food, which desire is the chemical affinity of atoms, then the Amœba hungers. This, Professor E. D. Cope[1] assigns as "the primitive desire and a form of pain. This was followed by gratification, a pleasure, the memory of which constituted a motive for a more evidently designed act, viz., pursuit."

Dividing primitive desires arising from (or with, if you wish) the atomic affinities into those which subserve and those which oppose assimilative processes, we have the origin of pain and pleasure, under which two heads all conscious workings may be classed.

Pain increases with the quantity of atoms unsatisfied. As long as there are protoplasmic molecules with affinities, the number of them wanting food increases the desire (attraction directly as the mass). Of course as soon as destructive starvation breaks down the molecules the desire ceases.

This is evident in the final loss of desire for food in extreme deprivation in man.

All unsatisfied desire is painful, as:

Hunger in the absence of food.

Desire to move about while disabled from so doing.

Desire to excrete when prevented by any cause.

In the act of satisfying desires pleasure is apparent:

Hunger appeased.

Movement unconstrained.

Emunctories unobstructed and excretion active.

All pains and pleasures are relative and intense in proportion to the precedence of one or the other extreme.

The pangs of parturition are obstructive excretory, and what obstetrician has not noticed the happiness of accomplishment by the mother.

A pleasure is often wholly due to the preëxistence of pain, and bearing upon the evolution of the reproductive excretory cellular into a desire which in its influence upon animal life is second only to that of hunger, this relativity must be borne in mind. The pleasurable anticipation of eating is a memory, the physical basis of which in the Amœba is a motion of the molecules involved in assimilation; their activity, their tension (the hungry Amœba is always more active than when fed). The reproductive excretory is in the Amœba scarcely to be called a desire, so dependent is it upon the performance of the assimilative act. The desire is invoked in exact proportion to growth from assimilation, provided other means of consumption of this growth are not operative.

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[1] Origin of the Will, *Penn. Monthly* for June, 1877, p. 446.

This is obvious throughout all animal life. When hunger is extreme the sexual desire is absent. Full meals sometimes excite voluptuous feeling. The repression of this excretory desire for a time becomes painful until readjustment enables vicariation. The desire to excrete the sperm cell is the male peculiarity, the desire, when present, of the female being, as shown in the *Science* article, identical with hunger. It is the hunger of the ova which are part of the female and which by differentiation have come to be capable of satisfaction in the manners to which they have grown.

From the synamœba stage, with its denser envelope preventing the escape of the cells for a longer period this sexual excretory desire would increase differentiation of the sexual hunger from the general hunger, is shown in the Drysdale and Dallinger monad.

C. M. Hollingsworth[1] on the "Theory of Sex and Sexual Genesis," assigns causes determining sex: "Since germ cells are large and sperm cells are small, it may be at once inferred that where they are formed in different parts of the organism, the parts in which germ cells or their producing organs are formed, must be parts in which the conditions are especially favorable to nutrition; and that the parts in which sperm cells or their producing organs are found, must be relatively unfavorable to nutrition and favorable to cell division."

"The hypothesis is that a *relative* preponderance of the conditions on which cell division depends causes the formation of the female or male generative organs, or determines the sex of the individual."

Extending this to the Amœba the pure relativity of sex is seen.

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[1] AMERICAN NATURALIST, July and August, 1884.

If the Amœba had undergone differentiation above some form by which it was engulfed, it could be regarded as the male. If it were swallowed by a synamœba then it is the female cell, and the product of this sexual eating would be either male or female—synamœba or amœba according to the preponderance of differentiating influence or the disposition to increase by fission on the resulting fused mass.

Desires consisting of atomic tensions or affinities, the conditions of continuance or satisfaction of desire, involves feeling or sensation, a low form of consciousness; this is justified in considering our developed similar states during the same processes of hungering, eating, etc., and as in us repletion discontinues desire, so does it in the lowest form of life we are discussing.

The sensations involved in assimilation would be difficult to separate from those concerned in pseudopodia-protrusion or general locomotion, as they are identical in effect in the Amœba; admitting their identity, it is easy to see how, by invagination of the ectoderm the later differentiation could occur by an enteric tactile developing in one direction while the ectodermal would change with direct reference to locomotion or prehension. But, as even when the enteron is formed, a prehensile tactile sense is retained and developed, analogies between the same distributions to external and internal parts remain though the sensations in many respects differ. The passage of materials in the intestines awaken few feelings so long as the adjustment is not disturbed, on the same principle that we do not feel external ordinary stimuli perpetually recurring.

Pressure is the feeling of constraint, interference with molecular and mass movement, it is a painful state of consciousness arising from the inhibited movements, the desire to move being consequent upon proper assimilation, and is referred to an interference with that function.

The hunger pain and appeasing hunger pleasure are due to and consist in chemical tensions and release from tension, the absence and presence of certain molecules. This carried up the scale of Metazoa convinces us that desire, feeling, sensation reside *in every living cell in the body*, and are not seated exclusively in nerve tissue. With the differentiation of function there will proceed changes of degrees of intensity of certain feelings in those living cells, but the fundamental hunger pain and pleasure of its gratification are never differentiated out of existence in any cell.

Desires, feelings, sensations, consciousness, cognitions, ideas, memories, emotions, etc., are one and all *conditions* of the molecules of the cells, and in the ravenous though unavailing appetite of some diseases wherein nutrition is at fault, the feeling is shown not to be solely located in the intestines but all over the body, and the inability of physiologists to locate centers for desires in the brain is explained. Whenever the exhibition of a feeling or a feeling itself has been destroyed through injury, it has been through failure of the *tracts* which convey molecular movements generated by such feelings from the now nervous bodily cells wherein those feelings are highly developed. *The nerves are pure association systems, and where the feeling aroused in an organ had become, through constant repetition, associated with certain other feelings or with a motor expression, then nerves of association would be built up through least resistant lines.*

The organism consisting in the sum total of the life activities of its cells, the dissociation of the organism from its locomotory organs, the legs, cut off the ability to walk, and paralysis of strands leading to the legs dissociate similarly.

Cutting off the organ of special sense or destroying its tracts similarly dissociate. There is a difference between cells acting for themselves or acting unitedly with others.

Returning to our Amœba, the mobile granules and molecules moved with every impulse. Its sensations were motions and its motions sensations, the two were inseparable. With a change in the density of its ectosarc, retarding fission, the morula form arose and in the break of the envelope Amœbæ are, as might be expected, liberated, but they have inherited this molecular development of ectosarc induration and develop into synamœbæ as did its parent.

The planæada developed cilia through a similar law. Owing to the difficulty of withdrawing pseudopodia once protruded, these atrophied into vibratile organs through starvation, and the hunger motions of the cells set up oscillations of the cilia which, subserving the life purposes better, were perpetuated and the motions of the cells adjusted themselves to the necessity and brought the environment food to itself by causing eddies, and a new means of locomotion arose. Still sensation and motion were identical, for the molecular movements constituting sensation ended in their summation of motions into gross locomotory motion, except that the cilia were organs of locomotion while the body remained sensitive. We may regard the cilium as formed of dead material in the main, Dallinger and Drysdale's monad rejected it in eating its companion. This would shadow forth the possibilities of a set of ciliary vibrations becoming known to the animal as tactile locomotory, differing from, though ministering to, hunger sense, and a change in the aggregation of the cell granules would follow. When the cell granules moved in keeping with the ciliary motions either the locomotory memory or act was aroused, if in accordance with hunger movements then the memory of hunger was aroused and this could react on the cilia to move them. When the ectoderm reached a stage of hardening admitting of no more strain upon it, the central contents transuded by some means, probably temporary rupture. The gaseous and watery contents escaped and the animal collapsed into the gastræada stage. The enteric cilia still remain as originally developed, but of course changes between ectodermal and endodermal experiences would differentiate the two areas. The inner remained subject to constant encounters, or nearly so, and the outer had the brunt of every change.

The acœlomotous Turbellaria appear to me to be more of an aberrant type not in our phylum, many of the forms have undergone much development. The delamination origin of the gastrula stage could be one of those ontogenetic short cuts often made in copying phylogenesis, the end attained being the same.

The Scolecid presents the most evident progress toward development in the vertebrate direction. Its cœlom contains the first nutrient fluid allied to blood, but its circulation is not established. The denudation of the useless external cilia, though occasionally developed into stiff setæ, in a turbellarian follow the locomotory process, changing to that characteristic of worms, elongation and contraction of the body length. Hubrecht's Pseudonematon illustrates this movement, through the alternate contraction of longitudinal and circular muscles with a plexiform nervous system between. The motion is in some respects similar to the flow of amœba granules forward into an arm, but organization has restricted this to a to-and-fro motion. The shape of the body rendering this the easiest mode of progress, the sum of the life activities act in least resistant lines to elongate and then contract the worm. Cause and effect exchange places in the circular fibers, being placed, through the motion of elongation, in a state of inertia, enabling the contraction of the longitudinal with consequent adjustment of the circular fiber molecules, so they can act to advantage. The repetition of these two opposed motions through the epidermal confinement of the skin, rendering them about the only ones that could be made, initiated by the attractive affinities of the protoplasm, finally developed the contractile tissue. The ventral location of the nervous system in the Errantia and others is due to development through use of that region differentiating locomotor areas from the epidermis, and in Insecta it is the persistence of the phylogenetic origin. In the worm stage the external tactile becomes fully developed through the heterogeneity of molar vibrations to which it is subjected.

One method of locomotion being possible, another is also possible, differences or variations in one or the other, such as could be caused by mechanical means, could result in a sinuous movement arising from want of rigidity in the worm length. A complex of causes, simultaneous and successive, operate to change the usual mode of locomotion and introduce so-called compound reflexes.

The formed tissue, of which Beale speaks, is often excrementitious, and has, through being useful, been retained by the cells. The sandy covering of the rhizopod, *Astrodiscus arenaceus*, may have been " selected " by agglutination of the envelope with the particles, or the shell of a mollusk may form through excretory processes or a covering may be acquired by squatter right as with the hermit crab. It matters little to the animal. The fighting cock will use the steel gaffs with as much gusto as though they had grown from his legs, nor is the cell a particle more particular. If it find in its environment matter with peculiar properties it will, through " selection," eat what it can and excrete the rest. If the excreted material have enough affinity for the cell to remain in its vicinity, and a life process is subserved by that fact, things chemical and mechanical in nature will conspire to associate the material with the cell. I regard nerve granules, such as are found arranging themselves or being arranged into first plexuses of fibers and then definite tracts, as having arisen accidentally. As the rhizopod could not have acquired his overcoat where there was no sand, the ancestral worm which picked up a nervous system could not have done so in the absence of assimilable phosphates. The resulting nervous system became more and more definite in tract formation as motions became more and more definite between parts. These nerve granules had a molecular mode of action altogether different from anything experienced before by the animal. In higher forms the cell substance, which had the particular ability to excrete or secrete it (relative terms), formed along the area of the plexus and tracts, next an encapsulating membrane formed about it, in obedience to ordinary physiological and pathological processes that an intermediary substance will be attracted and form around tissues or even foreign substances as a resultant of the mode of operation of the two tissues. In due time areas of nerve granule generation find in itself small plexiform areas which are turning points of direction for the molecular nerve discharge, and by encapsulating these the nerve cell is formed, which I regard as having no other functions than a histogenetic one aside from the molecular impacts passing through it. From protoplasm exuding the nerve granules the nerve cells develop to that office; from indifferent tissue forming cartilage, some of the latter form osteal cells.

A plexiform rudimentary nervous system conveys irritations over the body. When the discharges become definite the linear arrangement appears as in the ascidian embryo, the head end developing through tactile and rudimentary sense organs determining there with frontal impact of environment. Most influences acting to excite the squirt or vermicular motions from mouth to anus, a method of locomotion and ingestion at the same time.

It is easy to see how the mechanical perforation of a cœlenterate sac caused the enteron to be completed, but the origin of the circulatory system is not so evident. The enterocœle is in direct communication with the enteron in cœlenterates and the fluid it contains, as Huxley says, "represents blood," it is nutrient; the lacunæ of some worms are the next step toward a blood vascular system. The pseudo-hæmal system of the Annelida contains a substance resembling hæmoglobin, and with these facts before us we may construct the vascular system and its workings in some such way this: Cœlom, a receptacle for a fluid containing nutrient matter which had strained through the endodermal cells and through interstices between them. Next the appearance of hæmoglobin or its equivalent in the cœlom. The peculiar properties of this substance consist mainly in its solubility by alkaline fluids and its affinity for oxygen, "which is linked to it by ties so easily broken that it can be transferred to other easily oxidizable bodies existing by its side, that it can be given up when its solutions are gently heated in vacuo or agitated at moderate temperatures with large quantities of inactive gases, as nitrogen or hydrogen."[1] This oxygen carrier next formed a cell especially adapted to its transportation.

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SOME APPARENTLY UNDESCRIBED INFUSORIA FROM FRESH WATER.

BY ALFRED C. STOKES, M.D.

THE Infusoria whose descriptions are appended have as yet been observed only in the shallow ponds of Western New York, although they doubtless occur as plentifully elsewhere. Near the pretty village of Olean, in the bosom of the western hills, they pass their little lives amid attractive surroundings. Scarlet clusters of the cardinal flower and great bunches of yellow primroses make brilliant the shores of their aquatic haunts, while tall *Rubus odoratus* holds it purple roses aloft in the warm air, and *Anemone pennsylvanica* lifts its white blossoms above the "lush and lusty grass." A bird chirps in the shading maple boughs, a frog cries and splashes into the pool amid the Myriophyllum and Utricularia; a meditative cow gazes quietly at the intruding biped, and the blue sky bends above, and the blue mists rest in the hollows of the distant mountains. The placid water teems with life. A furrowed Euglena, hitherto undescribed and unseen by the eye of man, rotates like an animated screw in and out among the utricles and leaflets of the water weeds.

This green creature, which I have named *Euglena torta,* bears the remotest resemblance to any known member of its genus. The parenchyma is as usual uninterruptedly green, but the characteristic features are the spiral grooves or keel-like ridges traversing the entire body from anterior extremity to posterior acumination, where they are lost in the origin of that colorless caudal prolongation. The animalcule is but slightly flexible and apparently not changeable in shape during life. After death by poisoning the ridges and

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[1] Gamgee's Phys. Chem. of the Animal Body, p. 91.